The Surficial Geology of the Naugatuck Quadrangle

WITH MAP

Open Map

RICHARD FOSTER FLINT

STATE GEOLOGICAL AND NATURAL HISTORY SURVEY
OF CONNECTICUT

DEPARTMENT OF ENVIRONMENTAL PROTECTION

1978

QUADRANGLE REPORT NO. 35

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FOREWORD

Richard Foster Flint, the author of this report, died on June 6, 1976, soon after this map and manuscript had been prepared. It is appropriate at this time to pay tribute to the major contributions he has made to Connecticut geology. For years he has been a world authority on the Quaternary era, conducting field work and lecturing in South America, Europe, Asia, and Africa. His first major work on glacial geology came soon after he joined the Yale Faculty when the Connecticut Geological and Natural History Survey asked him to study the glacial geology of Connecticut. The field work and report were done in the summers of 1927, 1928, and 1929, and the report, *The Glacial Geology of Connecticut*, Connecticut Geological and Natural History Survey Bulletin 47 (294 pages, 1 large map), was published in 1930. He had already published shorter papers in scientific journals and had given lectures before scientific societies which had aroused great interest in his ideas of downwasting and stagnation as opposed to the conventional "normal retreat" in the last stages of Continental glaciation. Bulletin 47, with the map of the glacial deposits on the scale of 1:125,000, described the glacial deposits in considerable detail and gave the evidence he saw for stagnation and downwasting. For years geologists debated "stagnation" as opposed to "normal retreat" and many field trips gave opportunity for discussion. Moreover, his map of the glacial deposits even at the scale of 1:125,000 was a valuable tool in the hands of highway engineers and planners, and those in search of usable sand, gravel, and clay deposits.

Though Flint continued to publish papers on Connecticut geology in professional journals and was one of the editors of the glacial map of North America, the next period of direct activity with the Geological and Natural History Survey came after 1950 when the State had been remapped with larger scale (1:24,000) modern topographic maps. The State Survey had already started detailed bedrock maps on a quadrangle basis. Dr. Flint took part in discussions which led to the decision to make quadrangle maps showing the surficial deposits. He advised on personnel, critically reviewed manuscripts of other authors, and in addition, he himself mapped the surficial geology of 10 quadrangles published in 6 quadrangle reports. These are in addition to the two (Haddam and Naugatuck) now being issued.

The new larger scale maps are very timely with the increasing interest in land use. Dr. Flint has made major contributions to geology and to the State, and its citizens have benefited greatly both from his published work and from other work he and his students did in Connecticut.

As a Commissioner and later Director of the Connecticut Geological and Natural History Survey from 1947 to 1971, I found it a great privilege to work with such a distinguished geologist as Richard Foster Flint.

Joe Webb Peoples

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The Surficial Geology of the Naugatuck Quadrangle

by

Richard Foster Flint

ABSTRACT

The Naugatuck quadrangle lies in the southwestern part of the Eastern Highland of Connecticut. Features made by glacial erosion include striations and grooves, whaleback knobs, and streamline hills. Till of Late Wisconsin age covers much of the area, although over parts of many hills and ridges it is thin or absent. The glacial features have resulted from the passage of a thick ice sheet across the area, probably somewhat more than 15,000 years ago. Older till of unknown age is exposed at a few places, and probably underlies much of the quadrangle. As the Late Wisconsin ice sheet melted, its wasting margin formed temporary, irregular residual masses in the larger valleys. Stratified drift consisting of sand and gravel was deposited upon and around these, as well as in adjacent valleys already free of ice.

While stratified drift was being built up, winds picked up from it sand and silt, which they deposited as thin blankets over adjacent areas. Streams generated by the local rainfall cut into and greatly dissected the stratified drift. Most of the resulting waste was exported from the quadrangle but part of it was deposited as alluvium along the floors of valleys. In many shallow basins in bedrock and glacial drift, organic matter has accumulated in swamps.

Substances of actual or potential economic value include ground water, sand and gravel, and till. In places the terrain has been altered conspicuously by excavation and by deposition of artificial fill.

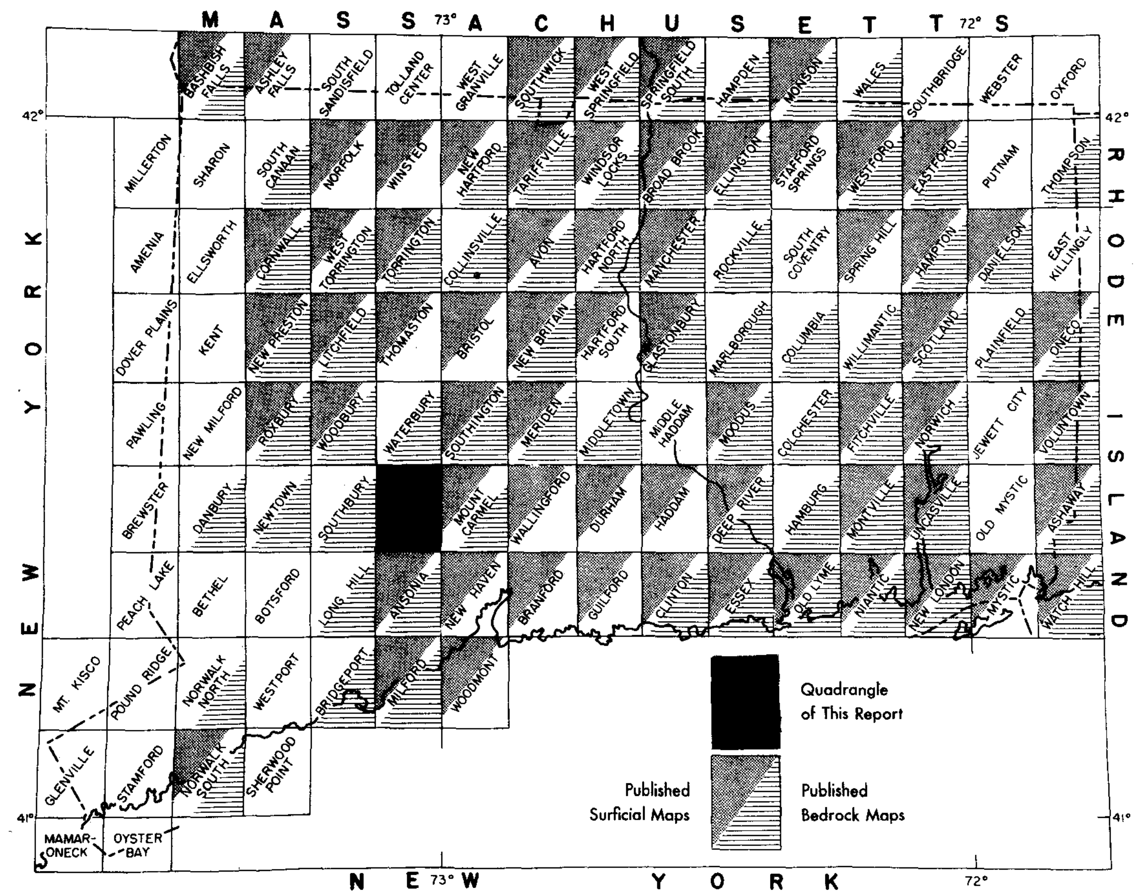

Fig. 1. Map of Connecticut showing location of the Naugatuck quadrangle and of other published quadrangle maps.

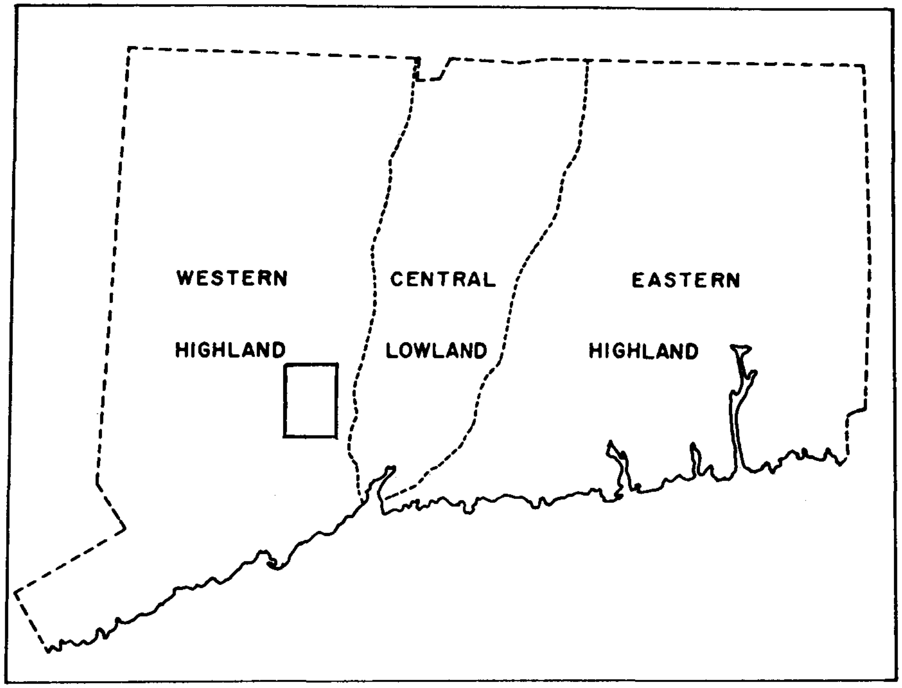

Fig. 2. Map of Connecticut showing boundaries of its three natural regions and the location of the Naugatuck quadrangle.

INTRODUCTION

The Naugatuck quadrangle (fig. 1) is an area of about 55 sq mi. in the central part of southern Connecticut, within the region known as the Western Highland (fig. 2). The quadrangle lies within New Haven County and includes parts of the towns of Middlebury, Naugatuck, Prospect, Oxford, Beacon Falls, Bethany, Seymour, and Woodbridge. The chief centers of population are Naugatuck, Beacon Falls, and Seymour.

The surficial geology was mapped on the scale of 1:24,000 in 1974 and 1975. Data were obtained mainly from observation of natural and artificial exposures, test holes made with hand tools, and analysis of land forms. Subsurface information was obtained from the U.S. Geological Survey.

In Connecticut the surficial materials (the nonconsolidated materials that overlie bedrock) are chiefly glacial in origin. Here surficial geology and glacial geology are nearly synonymous.

That southern Connecticut had been overrun by glacier ice was firmly established by J. D. Dana (1870, 1871). General discussion of the glacial features of Connecticut, although without special reference to the Naugatuck area, can be found in publications by Rice and Gregory (1906, p. 227-259) and Flint (1930, 1934). A. J. Ellis (1916) published a map and brief discussion that included the Naugatuck quadrangle. A report and map by J. S. Brown (1917) include the parts of Woodbridge and Bethany that lie within the quadrangle.

Acknowledgment is due to William McKeever for a manuscript map showing locations of striations in Seymour, Beacon Falls, and Bethany.

BEDROCK

The bedrock geology of the Naugatuck quadrangle was mapped and described by M. H. Carr (1960). It consists primarily of subparallel belts of folded metamorphic and igneous rock of Early and Middle Paleozoic age, mostly foliated, with their belts of outcrop trending irregularly NE-SW. These rocks are mainly schist and gneiss. Thin diabase dikes of Triassic age intrude the metamorphics, closely following their trend. The most conspicuous one is exposed discontinuously for a distance of about 4 mi. In the Southbury quadrangle, adjacent to the Naugatuck quadrangle on the west, there are similar diabase bodies as well as reddish-brown sandstone layers, also of Triassic age. Both sandstone and diabase have contributed, to a minor degree, to glacial drift in the Naugatuck quadrangle.

The area of origin of some of the metamorphic and Triassic rock fragments in the glacial drift can be identified. This permits determination of the ice sheet's direction of movement, a direction compatible with that determined from glacial striations, as described in a following section.

Bedrock is exposed as small individual outcrops in areas covered by a nearly continuous cover of glacial drift. In some hill areas, however, the blanket of drift is so thin and discontinuous that exposures of bedrock are numerous and closely spaced. The bedrock outcrop areas shown on plate 1 include those observed during the course of field work and some of those plotted by Ellis (1916, fig. 3).

Following the author's death, the bedrock outcrop data was recompiled by James L. Rolston of the Connecticut Geological and Natural History Survey using additional information.

TOPOGRAPHY

The surface of the area (pl. 1) is irregular, rising northward from the shoreline to a maximum altitude of 900 ft at Woodruff Hill near the northwestern corner of the quadrangle. Another high area is Andrews Hill (870 ft), 2 mi. west of the center of the municipality of Naugatuck. The lowest altitude, about 55 ft, is at the intersection of the Naugatuck River with the southern edge of the quadrangle.

Many of the topographic features of the map area tend to be elongate in N-S to NE-SW directions, reflecting structural trends in the local bedrock. The individual bedrock units differ somewhat in erodibility, as judged from the average altitude of each unit. A mechanical measurement of average altitude of each of seven bedrock units in the Naugatuck quadrangle, followed by statistical comparison, showed that Straits Schist and Ansonia Gneiss underlie the highest areas, indicating that they are the two least erodible rock types in the quadrangle. Their comparatively great resistance to erosion is probably due to their high quartz content and their widely spaced joints.

The valley of the Naugatuck River is narrower and has steeper sides (pl. 1) and a steeper gradient where it is cut into these two resistant rock types than elsewhere. Thus the valley is somewhat more open between Union City and Naugatuck, where the bedrock is Waterbury Gneiss, than south of Naugatuck, where it is Straits Schist and Waterbury Gneiss.

In areas of gneissic bedrock, glaciation has, in places, quarried out many boulders, leaving a rough surface characterized by small depressions and knobs. Examples are evident on the southern part of Tobys Rock Mountain in Beacon Falls.

Another influence on local topography is the varying thickness of the till that overlies much of the upland area, as discussed in connection with the description and distribution of till. Uplands with smooth topography generally expose till in roadcuts and other artificial excavations, whereas uplands marked by irregular topography more commonly expose bedrock, in many places with numerous boulders lying on the surface. It seems unlikely that this difference results wholly from local differences in thickness of the till mantle; probably it antedates the till, at least in part. Smooth pre-till topography would have led to deposition of a continuous blanket of till, whereas rough topography was conducive to discontinuous deposition of till and to glacial quarrying of rock from the lee slopes of bedrock hills, creating numerous boulders.

The Naugatuck district forms part of a coastal belt of dissected hilly country that extends across Connecticut (Flint, 1963). Within this belt hilltop altitudes decline southward at an average rate of about 50 ft/mi., and the whole surface passes beneath Long Island Sound.

Except in the larger valleys, the covering of glacial drift that overlies bedrock is generally so thin that it does not mask the forms of the bedrock hills. In many places it masks only the small details of relief, and some hills (such as the small hill of granite on the northern shore of Peat Swamp Reservoir at the southern edge of the quadrangle) have almost no drift on their surfaces. However, other hills—most of them of streamline form—seem to have been heightened by accumulations of drift. Round Hill, 140 ft high, near the southeastern corner of the quadrangle, exposes no bedrock and may consist of a substantial thickness of drift. The long axes of a number of hills, such as the southeastern unit of Woodruff Hill and the high hill between Swan Lake and Bee Mountain Road, both in Oxford, parallel the structure of the underlying bedrock. In contrast, other hills of similar form, such as the highest part of Rimmon Hill in the southwestern part of Beacon Falls, trend across the rock structure. It may be that the former group were basically created by preglacial erosion and later merely smoothed by glaciation, whereas the latter group were shaped by glacial action. Without detailed information on the form of the bedrock surface beneath the glacial deposits, it would be impossible to determine whether or not this is the case.

In the valleys of the Naugatuck River and some of its tributaries, bedrock relief has been reduced by filling with glacial drift, in places more than 100 ft thick (Grossman and Wilson, 1970, p. 17). With these exceptions, the relief of the area is attributable mainly to the irregular surface of the bedrock, which in its broad features acquired its form before glaciation.

DRAINAGE

The area of the Naugatuck quadrangle lies within the drainage basin of the Naugatuck River, a major stream that flows southward, as do the other major streams in Connecticut. The streams tributary to the Naugatuck are spaced rather uniformly, but their patterns are distorted (fig. 3).

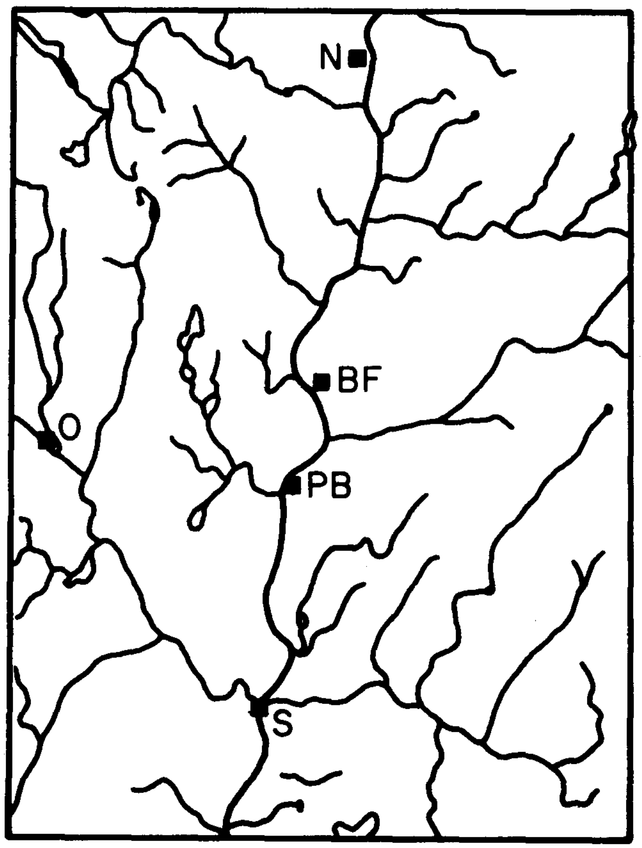

Fig. 3. Drainage lines in the Naugatuck quadrangle. BF = Beacon Falls, N = Naugatuck, O = Oxford, PB = Pine Bridge, and S = Seymour.

Many of the irregularities have resulted from the influence of bedrock. When viewed as a whole on a map of bedrock geology (Carr, 1960, pl. 1), the drainage pattern is seen to be related to rock structure and rock composition. Segments of many streams parallel the foliation of metamorphic rock, and parts of two streams (Rimmon Brook in Seymour and Hockanum Brook in Beacon Falls) flow on a diabase dike that is susceptible to weathering, relative to the adjacent rock. The most conspicuous example of bedrock control of drainage pattern is in the northern part of the quadrangle, where Long Meadow Pond Brook and Beacon Hill Brook, together forming an S curve 6 mi. long, follow the Waterbury Gneiss, close to its contact with the overlying more resistant Straits Schist. These and other local adjustments of streams to the rock beneath them imply a protracted period of erosion that might have occupied as many as 200 million years.

This general relationship between stream positions and bedrock characteristics is much like what would be expected had the region not been glaciated, suggesting that glaciation had little effect on the positions and forms of valleys and hills, which evidently were present before the glacial invasion. On the other hand, the weathered regolith that certainly developed on the bedrock surface in preglacial time is not present; it must have been removed by glacial erosion. Regolith on similar rocks in the nonglaciated region of eastern United States is at least 5-10 ft thick. Hence it can be inferred that glacial erosion stripped off a surface layer at least a few feet thick but did not remove enough rock to alter the positions of streams or to destroy the close relationship between altitude and lithology that had developed during a very long period of preglacial time.

There is little evidence of the alteration of stream patterns by glaciation, as seen in many parts of the United States. Evidently, at the onset of glaciation, the streams had become so well established in well-marked valleys that they could not be dislodged permanently by the rather short-lived occupation of the valleys by ice. Exceptions are extremely minor. Small streams, such as Towantic Brook near its head, Hockanum Brook at the Beacon Falls/Bethany Town Line, and the headwaters of Bladens River are interrupted by swamps or ponds, some of them occupying shallow basins created by the irregular deposition of glacial drift. The presence of such basins results from the recency of glaciation; the time has been too short to permit the re-establishment of stream flow uninterrupted by basins.

None of the lakes within the area is known to occupy a wholly natural basin; all were created, or at least deepened, by the building of artificial dams. The lakes include water-supply reservoirs, present or former mill ponds, recreational ponds, and basins excavated in sand-and-gravel pits.

GLACIAL-EROSIONAL FEATURES

Striations and grooves, etched into the surface of bedrock by rock particles embedded in the base of flowing glacier ice, are exposed at some places within the map area. Their lengths range from a few inches to a few feet. For at least three reasons, the areal distribution of the observed examples is very spotty: (1) the gneissic rock widely exposed in the quadrangle does not accept erosion readily.[1] (2) The bedrock is rich in biotite, hornblende, and other minerals that decompose readily when exposed at the surface, and so poorly retain the marks caused by abrasion. (3) Most exposures of bedrock in the numerous sand-and-gravel pits were so thoroughly scoured by the streams of glacial meltwater that deposited sand and gravel upon them that any former glacial markings have been scrubbed off.

Striations or grooves were recorded at 19 localities, where, as shown on plate 1, the bearings range from S 2° W to S 50° E. The average is S 30° E (fig. 4). Measurements in the Mount Carmel quadrangle (Flint,

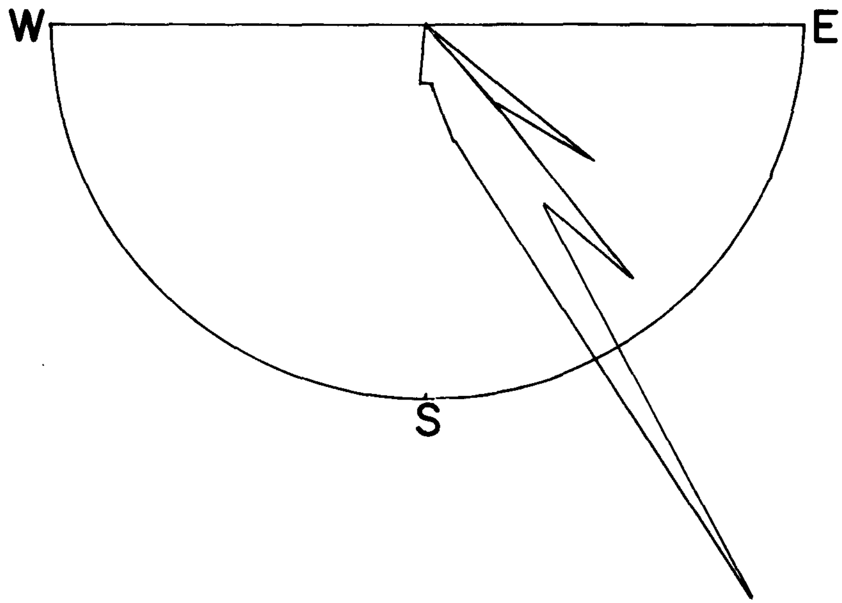

Fig. 4. Rose diagram showing trends of the glacial striations measured within the Naugatuck quadrangle.

1962, p. 6), adjacent to the Naugatuck quadrangle on the east, show bearings that trend SW. In the nearby (fig. 1) New Haven and Woodmont quadrangles (Flint, 1965, fig. 3) and in the Ansonia and Milford quadrangles, to the south of Naugatuck (Flint, 1968, fig. 3), two trends were noted—SE and SW, the latter trend apparently the later of the two. In the Naugatuck quadrangle only a SE trend was measured; it probably correlates in time with the SE trends measured in the other quadrangles.

[1]Of the rock types that crop out within the quadrangle, by far the most susceptible to abrasion is the Orange Phyllite. That unit, however, is confined to an area of only a little more than a square mile, and is almost completely hidden beneath glacial drift.

At a few places within the area, bare knobs of bedrock are smoothed to whaleback form by glacial grinding. Accessible examples are the ovate hill, 0.25 mi. long, on the northern shore of Peat Swamp Reservoir in Seymour and a knob 100 ft south of the dam at Seymour Reservoir No. 4 in Oxford. Both whalebacks parallel structures in the bedrock; these structures seem to have guided the local flow of the ice sheet. At one point on the whaleback near Peat Swamp Reservoir a nested series of small crescentic gouges was observed, the trend of the series paralleling the striations on the same whaleback.

STREAM-ABRADED BEDROCK

At many places within the quadrangle, bedrock now exposed has been abraded and smoothed by stream-borne sediment. The abraded surfaces are not like those shaped by glacial abrasion. They are smoother, more irregular, and lack striations. Many such surfaces consist of an irregular network of small, coalescent basins separated by narrow, cusplike ridges, and are smoother in their concave than in their convex elements. All those observed occur in areas of stratified drift, which in many places overlies or lies against the smoothed bedrock. This relationship implies that the abrasion was accomplished not by existing streams but by streams of meltwater that were active during wasting of the ice sheet.

Striking examples of stream-abraded bedrock occur (1) in the eastern part of a large sand pit, 800 ft north of Bridge Road, Beacon Falls, just northeast of the Ideal Manufacturing Co. plant, and (2) 1,400 ft northeast of the intersection of Candee Street and New Haven Road, Naugatuck, between an outdoor theater and a sand pit of the Mariano Sand and Stone Co.

TEMPORARY GLACIAL-STREAM CHANNELS

In several parts of the quadrangle are generally shallow, troughlike features 600 ft or less in length, with gentle sideslopes mantled with till. Some of them are probably floored with bedrock beneath thin swamp deposits, till, or cobble gravel. Such troughs cut across E-W-trending divides, at altitudes between 730 ft and 350 ft. They are believed to be preglacial low places occupied temporarily by streams of meltwater that drained areas dammed by wasting ice and that flowed, generally southward, into lower valleys less encumbered or unencumbered by masses of ice.

Several such features were identified with some confidence, but there are probably other channels, some occupied for extremely short periods. Five of these features identified on plate 1 cross the divide between Cold Spring Brook and Beacon Hill Brook at altitudes between 730 ft and 460 ft, another is along the eastern base of Rock Rimmon at about 370 ft, and three (not shown on plate 1) cross between Beacon Hill Brook and Hockanum Brook at about 580 ft. These channels are not conspicuous. One that is well developed occurs 0.4 mi. east southeast of Central High School, Naugatuck, at an altitude of about 350 ft.

These channels lie east of the Naugatuck River. No comparable channels were seen west of the river, probably because in the west the divides trend more nearly N-S than E-W (fig. 3). This enabled meltwater streams to escape along valleys without having to cross major divides.

GLACIAL SEDIMENTS

Sediments of glacial origin, collectively known as *glacial drift*, are of two general kinds: *till*, deposited directly from glacier ice, and *stratified drift*, deposited in streams or lakes created by the melting of glacier ice. Both kinds are present in the Naugatuck quadrangle. Both are discontinuous in distribution and extremely variable in thickness.

Till

GENERAL CHARACTER

Till consists of a mixture of rock particles of many sizes, ranging from large boulders to tiny particles of clay; however, at any one locality not all these sizes are necessarily present. Till forms a discontinuous mantle over the area. It covers much of the surface of the bedrock on hills and smaller valleys alike, and thereby shows that the bedrock had been sculptured, by weathering and by runoff of rainwater, essentially to its existing surface form before glaciation occurred. Because the major valleys are partly filled with sediment younger than the till, the till itself is exposed in them only rarely. However, borings made in the floors of valleys show that till underlies the younger sediment and, in turn, is underlain by bedrock. For example, the log of a test hole (Grossman and others, 1970, p. 25, test hole No. 4) on the western bank of Naugatuck River at the highway bridge in Naugatuck, shows 48 ft of gravel and sand underlain by 10 ft of till above bedrock.

Plate 1 shows that in the majority of the areas where bedrock is at the surface or close to it, the hill slopes are steeper than elsewhere. The presence of steep slopes depends to a considerable degree on bedrock minerals and structures, particularly foliation and jointing. In places, vertical or very steeply dipping foliation and joints could have been quarried by the ice that flowed over the rock. Large and small pieces of rock would have been split away from a hill and carried southeastward, leaving behind a steep clifflike slope. As long as it remained steep, no amount of quarrying would change the angle of the slope created in this way by the ice that flowed past it. For such cliffs to form, the structures need not have been at right angles to the direction of ice movement. Their trend needed only a component transverse to the "downstream" direction. An analogy is a carpenter's plane passing across the end of a board. Even if the plane meets the trailing edge of the board obliquely, bits of the wood will be chipped and split off.

In the Naugatuck quadrangle the areas where bedrock is mapped as being at or close to the surface commonly display exposures of bedrock, many of the clifflike. Such areas also have many surface boulders, most of them consisting of the local bedrock and having joint-controlled faces.

In contrast, most slopes that face "upstream" caused the flowing ice to deposit till over them. Similarly, the broad tops of many interfluves received a mantle of till sufficiently thick to conceal the bedrock except for sporadic exposures. The till mantle has smoothed topographic detail by filling small valleys and pockets in the surface, particularly on hillsides. Roadcuts, stream banks, and other surface exposures rarely show more than a few feet of till, and the greatest thickness seen exposed is 28 ft (on Chestnut Tree Hill Road, 1,300 ft southeast of the Chanko Pond dam in Oxford). In the 17 test holes in the Town of Naugatuck that penetrated till, the average thickness is 13 ft. The test holes are in valleys, where great till thicknesses are not expected; thicker till can be predicted on wide, smooth hilltops. Nevertheless, the average thickness of till in the map area probably does not exceed 20 ft.

The surface of the till is smooth. It has little relief that results from local variations in its own thickness, independent of the relief of the underlying bedrock surface. The glacier appears to have smeared till over the bedrock in a blanketlike manner.

The till includes a coarse fraction consisting of pebbles, cobbles, and boulders and a fine fraction consisting of sand, silt, and clay. As is general throughout much of Connecticut, the coarse fraction is conspicuous in surface exposures but, when measured, is found in most samples not to exceed 20 percent of the total. In some it amounts to less than 5 percent.

The pebbles, cobbles, and boulders in till are generally subangular, reflecting the joints and foliation surfaces in the bedrock from which they were derived. Most show some degree of smoothing and abrasion, acquired during their travel in the glacier. Corners and edges between facets are rounded, and the surfaces of a few (generally fewer than 3 percent) are scored with striations. A very few are well rounded; very likely these had been transported in streams before being last picked up by the glacier. The sand-size particles are mainly very angular, implying crushing while in glacial transport.

In some exposures the shapes of many particles (including big boulders) in the coarse fraction show that their surfaces are ragged fracture planes, modified little or not at all by glacial abrasion. These fragments may have been torn from bedrock by the glacier and transported without coming into frequent contact with other pieces of rock, or they may have resulted from crushing.

In composition, till commonly resembles the bedrock that immediately underlies it or that occurs within a short distance northward.

TILL TYPES, STRATIGRAPHY, AND CORRELATION

Till of two distinct types is exposed in the Naugatuck quadrangle. The first type, exposed in 1974 at only six places (pl. 1) is extremely compact and therefore tough; a stone pried out of it leaves a well-defined socket in the matrix. The coarse fraction is comparatively small and, within the boulder class, small diameters predominate. The fine fraction is an estimated 50-60 percent sand. This till generally possesses distinct fissility, a structure that consists of closely spaced, subparallel partings nearly parallel with the ground surface, and that may have resulted from plastering, by moving ice, of successive layers of wet, plastic sediment onto the ground. In places this till is distinctly jointed. In color (dry) it ranges from yellowish gray (5Y 7/2, according to the Munsell system of color classification, Goddard and others, 1948) to dusky yellow (5Y 6/4) and pale olive (10Y 6/2) and, close to the surface where oxidation is present, to yellowish brown (10YR 6/2). Lentils and ribbonlike bodies of sand occur, as well as discontinuous, nearly horizontal streaks, as much as 30 ft long, of widely spaced cobbles and small boulders.

This or a similar till was seen at one locality in the Ansonia quadrangle (Flint, 1968, p. 13), immediately south of the Naugatuck quadrangle, at one locality in the Mt. Carmel quadrangle (Flint, 1962, p. 9), immediately east, and at a few places in coastal Connecticut, east of New Haven (Flint and Gebert, 1976).

Till of the second type is less compact; indeed, it is commonly friable. The coarse fraction is larger and the boulder class includes many large individuals. The fine fraction is estimated to include about 70-75 percent sand. This till is fissile in some places but is not characteristically so, and is not cut by joints. It ranges from gray to yellowish brown, generally including slightly more red than does till of the first type, perhaps because its higher sand content makes it more prone to oxidation. In places this second type of till encloses small bodies of sand and pebbles.

A probable contact surface, poorly defined, between the two types of till was exposed in September 1975 on the western side of the Naugatuck sanitary landfill area on Huntington Hill. There the second type of till, 3 ft to 12 ft thick, appears to overlie till of the first type, at least 20 ft thick. If this is the case, the second type is the younger of the two. Whether these tills represent two distinct glaciations or are both products of a single glaciation is not established (Pessl, 1972), although if two superposed tills exposed at Lake Chamberlain, near New Haven (Flint, 1961) are counterparts of the tills in the Naugatuck quadrangle, there is at least some reason for believing that the Naugatuck tills are of different ages.

Whatever the stratigraphic correlation of the till of the first type, the second type probably was deposited during a late part of the Wisconsin Glacial Age of geologic time.

Erratic boulders

Erratic boulders, those composed of rock that differs from the bedrock upon or above which they lie, are numerous in the map area. Some of them lie free on the surface of till or bedrock; others are partly embedded in drift. Many exceed 5 ft in longest diameter, but only those with a diameter of 10 ft or more were plotted on the map (pl. 1). Thirty-four were mapped, and probably many others were missed in densely forested terrain. The largest seen, a gneiss on a high hill northwest of Bungay Road in Seymour, measures 17 x 11 x 9 ft, and is locally known as Balance Rock, probably because it directly overlies a surface of bedrock free of till. It is one of a cluster of five erratics each at least 10 ft long.

The longest of the mapped boulders lies in a large pit of the Waterbury Sand and Gravel Co., south of Salem Road near the northeastern corner of the quadrangle. It measures 18 x 8 x 6 ft, consists of gneiss and during pit operations, has been moved from its original position which was probably within the area of the pit.

The chief factors that determine the diameter of an erratic boulder in this region are spacing of joints and degree of development of foliation. Hence large boulders tend to consist of gneiss, which is both massive and widely jointed. Of the 34 mapped boulders, 22 are gneiss.

It is assumed that the large boulders in the quadrangle were emplaced during the latest glaciation of the region.

Stratified drift

KINDS OF STRATIFIED DRIFT

The sorted sediments, mostly stratified, that are deposited in streams and lakes derived from melting glaciers are collectively known as stratified drift. Some of this material was derived directly from rock particles in glacier ice, and some consists of reworked and redeposited till. Stratified drift is of two kinds, each an end member of a gradational series. One kind is *ice-contact stratified drift,* sediment deposited in contact with melting ice at or near the margin of a glacier. The other kind is *outwash,* sediment deposited by streams of meltwater beyond the glacier margin.

STRATIFIED DRIFT IN THE NAUGATUCK QUADRANGLE

Most of the stratified drift exposed in the Naugatuck quadrangle belongs to the ice-contact category. Outwash, although present, is not sharply separated from it and appears to have been deposited by short, shifting streams along and just beyond the lateral margins of the melting glacier. Both sorts of drift, apparently, were deposited while melting ice continued to occupy the larger valleys, forming temporary dams that created ponds and streams at much higher altitudes than those of the present-day drainage. Because of the complex and intimate association of the two kinds, it was impracticable to map them as two separate units. Hence all the stratified drift indicated on plate 1 is shown as ice-contact stratified drift, even though some exposures do not display proof that ice was present beneath or adjacent to the drift when the drift was deposited there. However, as already noted, the high altitudes of such exposures imply that ice was present not far away, in order to have generated streams far above their present elevations.

ICE-CONTACT STRATIFIED DRIFT IN THE NAUGATUCK QUADRANGLE

In the Naugatuck quadrangle ice-contact stratified drift consists mainly of sand and gravel with a little silt and trace amounts of clay. Visual examination of many exposures suggests a rough estimate, for the quadrangle as a whole, of 75-90 percent sand, 10-15 percent gravel, and less than 1 percent silt and clay. Most of the sand grains are "sharp" (very little worn by attrition), suggesting that they are mainly a product of the crushing of larger rock fragments and that they have been carried only short distances before being deposited. Most of the pebbles, cobbles, and boulders that constitute the gravel show signs of slight to moderate wear by stream transport; some have glaciated facets like those of stones in till.

The color of nearly all the stratified drift, when dry, lies within hue 5Y (Goddard and others, 1948), yellowish gray to dusky yellow. In places it grades into hue 10 YR, pale yellowish brown to yellowish orange. Much of the ice-contact stratified drift in the map area has one or more of these characteristics: great internal variability, poor sorting, large and abrupt changes in grain size both vertically and horizontally, inclusion of small bodies of till, erratic boulders, or flowtill (till-like sediment deposited by landsliding off adjacent ice), and deformation of the layers by subsidence or other displacement activated by melting of underlying or adjacent glacier ice. Rounding of individual particles, although highly variable, is commonly slight or only partial.

In addition, ice-contact stratified drift is characterized, in places at least, by constructional topography that includes basins (known as kettles), partial basins, irregular, knoll-like mounds (*kames*), and *kame terraces* gradually built up between the sides of a glacier and the sides of the valley it occupies. These features reflect the presence of irregular bodies of melting ice during accumulation of the drift.

Some of the drift with these characteristics, however, grades into sediment that consists chiefly of sand with no evidence of the presence of immediately adjacent ice during its accumulation. Such sand is believed to have been deposited in the temporary lakes that were dammed by ice in principal valleys tributary to the Naugatuck Valley.

Apart from differences in the influence of adjacent or buried ice, the character of the ice-contact stratified drift shows that it was deposited partly by streams and partly in lakes and ponds. The stream-deposited sediment commonly occurs in lenticular beds, each consisting of parallel layers inclined in a single (downstream) direction. The sediment deposited in lakes and ponds is characterized by delta lobes, foreset layers, parallel stratification (in places with rippled layers) and abundant dropstones (stones and boulders dropped from floating icebergs onto the lake floor). In places the stream sediment grades laterally into sediment of lake type, and in places the two types alternate in vertical sequence. Courses of foreset layers of sand, in one place having an amplitude of 60 ft, mark localities where streams of meltwater flowed into lakes. At some such localities, extensive exposures in sand pits show two or more delta lobes that merge laterally. In other places the layers of sand are parallel, thin, and nearly horizontal, and represent sediment deposited on the lake floors beyond the deltas. Many such floor deposits expose dropstones, some of them boulders as much as 6 ft in diameter, that have punched down and compacted the sand beneath them and that are covered with sand layers draped over their tops and sides. One such dropstone, exposed in a sand pit (and now probably destroyed) was a lump, 21 in. in diameter, of fine sand with many pebbles pressed into it. It must have been frozen when dropped; otherwise down-punched and draped-over layers could not surround it.

In some valleys tributary to the Naugatuck River, delta foresets dip up-valley, away from the Naugatuck. This implies that the sediment was built into the ponded tributary from the direction of the Naugatuck Valley, by meltwater escaping from ice in that valley. Escape of water from the ponds took place either *via* temporary channels across divides, as already described, or over residual ice. In the latter case no trace of the overflow would be likely to have remained.

In some tributary valleys the stratified drift forms distinct benches or terraces. Although no exposures were found at the lines of junction of two benches, the similarity of the material exposed in adjacent benches, and the smooth and uncomplicated character of the break in slope between them, support the belief that at many such places the lower bench was cut from the higher mass rather than built up against it.

These relations imply that as the masses of residual ice shrank by melting, the streams that flowed beside or upon them lowered their gradients and cut into deposits already made, with ice continuously present during the process. How much terracing of this kind occurred is not known, because the postglacial streams have eroded so much of the glacial material that a substantial part of the record has been destroyed. However, in the valley of Beacon Hill Brook, there are several local benches, the highest at altitudes of between 600 and 700 ft. Yet near the mouth of that valley, around Grove Cemetery, an area of conspicuous kames at altitudes of less than 300 ft implies that residual ice remained there until after it had abandoned the higher parts of the valley. But we do not know whether the higher masses of stratified drift in this or any other valley were, when fully built, separated from each other by residual ice and were therefore kame terraces, or whether they were joined together by a roof of sand and gravel that covered intervening ice and gave the valley the appearance of having a continuous sedimentary floor.

It might be supposed that after the tributary valleys had been entirely freed of ice, the ice remaining in the Naugatuck Valley would have given rise to a continuous, coherent body of outwash—a valley train. However, no convincing evidence of such outwash has been seen in the Naugatuck quadrangle, in the Ansonia quadrangle farther downstream, or in the Milford quadrangle north of Stratford (Flint, 1968, pls. 1, 2). Either no such outwash was built in the Naugatuck quadrangle or, because sea level stood far below its present position at the time when such outwash could have been built, any valley train in the quadrangle would today be buried and out of sight, covered by the alluvium and the existing channel of the modern Naugatuck River.

WIND-BLOWN SEDIMENT

In some areas of the quadrangle, patches of fine-grained sand, in places with small amounts of medium-grained sand, overlie the ice-contact stratified drift. Their observed thicknesses range from 3 ft to about 1 ft— too thin to be shown on plate 1. This sediment is unstratified. It is moderate yellowish brown, 10YR 5/4 (Goddard and others, 1948), darker than the drift that it overlies, probably because the patches are thin enough to have been oxidized by weathering. This patchy sediment is believed to have been deposited by winds that picked up the sand grains from exposed drift during the process of deglaciation, but before the exposed drift had become covered by sufficient vegetation to prevent erosion of loose sand.

Similar sediment in the Ansonia and Milford quadrangles (Flint, 1968, p. 27) is significantly thicker and more extensive than in the Naugatuck quadrangle, probably because it was deposited somewhat earlier in the deglaciation process, when the climate was slightly colder, the vegetation more sparse, and winds stronger and more frequent.

POSTGLACIAL SEDIMENTS

Alluvium and colluvium

Postglacial sediments in the quadrangle include alluvium, colluvium, swamp deposits, and artificial fill.

In the Naugatuck area, alluvium is the sediment deposited by postglacial streams and colluvium is the sediment postglacially moved down hillslopes by creep, slump, and related processes of mass-wasting. Colluvium is difficult to identify except in clean exposures, and where identified in the area it is very thin. Hence on the map it is included with alluvium, till, or bedrock.

Alluvium is thickest and most nearly continuous along the Naugatuck River, where it flanks the river channel, forming a ribbon that in places extends across the valley floor, between the bedrock-valley sides, through a maximum distance of nearly 1,000 ft. The sediments are of three distinct kinds: channel alluvium, floodplain alluvium, and alluvium of the flood of 1955. The areas in which all three can be seen include both sides of the floodplain 3,500 ft southward from the Seymour/Beacon Falls Town Line. The floodplain as a whole forms a comparatively smooth surface standing generally 10-12 ft above the river surface at mean low water. In a few places the highest areas reach 15 ft, whereas abandoned channels are as little as 5 ft above the river. The thickest single exposure of alluvium shows a minimum thickness of only 10 ft, but greater thicknesses probably lie beneath the surface. At one place channel alluvium was seen unconformably overlying ice-contact stratified drift.

Channel alluvium consists mostly of micaceous, medium- and fine sand with pebbles; it is gently and irregularly cross-stratified, and is pale to dark yellowish brown. It has been deposited in the river channel throughout much of postglacial time, and as the channel migrates laterally, such alluvium can form in any part of the floodplain. It is continually undercut and destroyed by the shifting river in some places while being deposited in others. Some of the channel alluvium forms point bars—crescent-shaped accumulations at the inner sides of bends in the channel.

Floodplain alluvium is deposited during normal floods, in which water fills the river channel completely and spreads laterally over the floodplain in a thin, slowly moving sheet. Such alluvium consists mainly of micaceous sand, mostly fine grained, lying in faint sub-parallel laminae, with lentils of coarser sand and of blackish, humified silt, as well as pockets of organic trash consisting of leaves and twigs. Rooted in its upper surface in some places are the stumps of many trees, some large and some bearing saw marks. All the stumps are covered with or exhumed from alluvium of the 1955 flood or a similar flood, and the surface in which they are rooted is that of the natural floodplain as it was at some time before 1955.

The third kind of alluvium was emplaced by the disastrous flood of October 13-15, 1955, and perhaps also by unknown earlier floods of similar magnitude. It consists of small boulders up to 4 ft in diameter, cobbles, pebbles, and sand, together with a large proportion of flat-lying tree trunks and poles, railroad ties, pieces of lumber, rubber tires, pieces of iron, rubber and plastics, bricks, masonry(including a flight of six stairs), and industrial trash. Exposed sections show little apparent stratification. A thickness greater than 3 ft was not observed; however, this type of alluvium is conspicuously scattered over floodplain surfaces, particularly along the inner sides of bends in the river channel. Although a considerable part of this trash-filled alluvium was probably removed during clean-up in the years immediately following the flood, an impressive amount still remains.

In addition to the alluvium along the Naugatuck River, ribbons of sandy, pebbly alluvium, mostly of the channel type, occur discontinuously along principal tributary streams, and generally stand 3-8 ft above the stream surfaces at low water. At the stream mouths, such alluvium appears to be flush with that along the Naugatuck, constituting a single graded system developed in postglacial time. Also, a number of steep hillside brooks have built inconspicuous small fans at the places where they enter wide valleys. They are identified by their surface form.

Swamp sediments

Swamps, most of them small and wooded, occur in upland areas of the Naugatuck quadrangle. The majority occupy shallow basins, some in till and some in collapsed stratified drift. A few occur along small streams where drainage is impeded by variations in permeability of the floor material. The swamp sediments, which underlie the living vegetation, consist mainly of muck, an olive-gray to dark-gray or brownish mixture of silt, clay, and fine sand, with a high percentage of comminuted decayed plant matter. They also include peat, which is nearly pure organic matter. The thickness of the swamp sediments in the Naugatuck quadrangle is unknown, but is unlikely to exceed about 10 ft. Elsewhere in southern

Connecticut much thicker accumulations are known, and preserve a fossil record of changes in vegetation and climate since the time when the ice sheet melted away, as indicated in a later section. A marsh in New Haven (Deevey, 1943, p. 726) yielded a 28-ft core, containing a record of fossil pollen that shows the kinds of trees and other plants that lived in the vicinity during approximately the last 15,000 years or less. The succession of vegetation shows, in general, progressive warming of the climate with intermediate fluctuation.

Artificial fill

Artificial fill consists of deposits made by human activity; these include railroad, highway, and building-construction fills and large accumulations of trash. Much of the fill material mapped was obtained from areas close to the fill bodies, but some of it was brought from distant sources. The largest bodies of fill within the map area are those related to the Route 8 Highway, schools, shopping centers, and large industrial plants along the Naugatuck River.

In densely populated areas much of the surface material underlying streets, driveways, and lawns is fill. However, fill was mapped only where it is known or judged to be at least 5 ft thick and where its area is large enough to be shown at the scale of the map. Areas of conspicuous artificial cutting that are continuous with areas of fill are mapped as fill.

WEATHERING AND SOILS

Where the contact between bedrock and overlying drift is exposed, the surface of the bedrock is fresh and unweathered, just as it was left after abrasion by ice or by meltwater. However, in places where no drift was deposited or where overlying drift has been stripped away by erosion, the bedrock surface is slightly but noticeably weathered. Weathering takes the form of slight roughening, slight bleaching, or oxidation. Along joints such weathering changes extend downward well below the surface. This is the extent of local postglacial weathering in bedrock.

In glacial drift and wind-blown sediments the most obvious effect of weathering is oxidation, which in most places is limited to a depth of 2-3 ft. Oxidation imparts a yellowish or brownish hue to the fine-grained particles in the drift, and also forms rinds of limonite on the surfaces of stones and boulders of rocks rich in iron-bearing minerals.

Within the thin zone of weathering, soils are developed. The Naugatuck quadrangle lies within the region of Brown Podzolic soils of northeastern United States. Brown Podzolic soils are imperfectly developed Podzols characterized, in forested areas, by a thin gray leached zone beneath a thin mat of partly decomposed organic matter. Such soils, having weakly developed profiles, are normally less than 30 in. thick. Within the map area there are a number of soil types, some of which were discussed by Morgan (1930). Because the area lies within a single zone of climate and vegetataion, local differences among its soils result mainly from differences in parent material, relief, and drainage. Of these factors parent material is believed to be the most important.

GLACIAL AND POSTGLACIAL HISTORY

Before glaciation of the region began, the principal valleys, ridges, and hills had already been shaped by long-continued erosion and, except in detail, were similar to those of today. The surface was mantled with regolith, perhaps thick, developed by weathering of the underlying bedrock.

In the Naugatuck quadrangle, as in several other quadrangles in Connecticut, the presence of two layers of till suggests that the entire region has been glaciated twice. Furthermore, evidence of more than two suites of glacial deposits on Long Island implies that the Naugatuck area must have been glaciated repeatedly. In the last glaciation, at least, an ice sheet flowed across the area from NW to SE. Because evidence of glaciation is present on the highest hills as well as in the valleys, it is clear that when the glacier reached its maximum extent, the area was completely buried beneath ice. The cumulative effect of this and earlier glaciations was to smooth, round off, and generally shape the hills and ridges into streamline form, to smooth and widen some of the valleys, and to remove most of the pre-existing regolith.

In the Great Lakes region the combined evidence of till layers and radiocarbon dates indicates that a group of related glaciations occurred within the last 70,000 years or so and that the last major invasion by ice culminated around 18,000 years ago. It is thought that at about this time the part of the ice sheet that covered New England reached its outer limit along a line on or south of what is now Long Island. At or near its limit, the glacier built the end moraines and outwash plains that are prominent features of the island. The outer margin of the ice sheet melted just rapidly enough so that, with the ice continually renewed by flow from the north, its margin remained in about that same position. Later, melting increased while flow was reduced, and the margin retreated northward across what is now Long Island Sound. During the retreat the ice sheet became thinner. Probably about 15,000 years ago, or somewhat later, the margin of the glacier had melted back to the line of the present Connecticut coast.

There ensued a period of several hundred years or more, when increase of flow or increase of melting or both caused the margin of the glacier to halt and to shift position slowly, forward and backward. End moraines along the Connecticut coast and eastward in Rhode Island were built at that time (Flint and Gebert, 1976).

Thereafter, thinning affected an increasingly wide marginal belt of the ice sheet, through which the higher hilltops appeared. At the same time the glacier began to flow more slowly. Eventually the ice became so thin that its outer or marginal part virtually ceased to flow and became nearly inert. Thinning progressively exposed the hills, while tongues and detached masses of ice remained in the larger valleys. Streams of meltwater flowed between the margins of such masses and the adjacent valley sides, and built up embankments of sand and gravel derived from the active ice farther upstream. In many places stratified drift completely buried residual masses of ice. In this way the ice-contact stratified drift was built and then gradually deformed by collapse as the ice melted. Thus during deglaciation of the Naugatuck area there was an ice-free zone to the south, then a zone of separated bodies of residual ice in the valleys, and finally a zone of continuous, thinning ice that extended far to the north.

From borings made in marshes and in the floors of lakes, the recovery of fossil pollen has yielded a record of the kinds of trees and other plants that lived in southern Connecticut during the last 12,000 to 14,000 years (Deevey, 1943, p. 726; Davis, 1969). During the deglaciation of southern Connecticut the vegetation consisted mainly of treeless, tundralike grassland; after deglaciation it changed to spruce forest and later to other conifers. Still later, a warmer climate induced the gradual development of the deciduous forest that we see today.

Within the Naugatuck quadrangle one stream after another ceased to be fed by meltwater and became dependent solely on local rainfall. Probably much of the dissection of ice-contact stratified drift occurred rapidly during this transitional time, when there was little or no vegetation to inhibit erosion. The small fans described under *Alluvium* may have been built then. The fans are poorly defined, possibly because they were built so early that mass-wasting has altered their forms.

The fact that outwash has not been surely identified along the Naugatuck River in the Naugatuck quadrangle, although present farther downstream, may result from lowered sea level. At the time of maximum extent of the ice sheets in North America and Europe, sea level was very low, possibly as low as —300 ft. As meltwater returned through streams to the ocean, sea level gradually rose. By about 5,900 years ago it had risen, relative to the land, to about 26 ft below the present mean sea level, as shown by a series of radiocarbon dates on wood and peat from beneath estuarine mud at several places along the Connecticut coast (Bloom and Stuiver, 1963). Thus, late in the deglaciation of the Naugatuck quadrangle, the Naugatuck River could have been flowing on a profile lower than today's sea level, so that any outwash then deposited might have been covered by more recent sediments and hidden from present view.

Throughout postglacial time the existing soils were forming beneath a cover of largely forest vegetation. The youngest soils are those on postglacial alluvium. The accumulation of peat in swamps and the postglacial return of forests have altered the landscape appreciably, but work of man—deforestation, cultivation of the soil, and construction of roads and buildings—has made far more conspicuous changes. When settlement of southern Connecticut by European people began in the 17th Century, all the land within the quadrangle, except for patches of bare rock, was clothed with forest. Today about 70 percent of the land area of Connecticut consists of woodland. The Podzolic character of the local soils reflects the influence of the forest cover.

ECONOMIC GEOLOGY

Sand and gravel

In the Naugatuck quadrangle the mineral material of greatest economic value is sand and gravel. Nearly all of it occurs in ice-contact stratified drift. The majority of active sand-and-gravel pits are in areas of such drift that consist chiefly of sand, which is easier to handle than are deposits containing cobbles and boulders, especially large boulders.

The principal pits known to have been in operation in 1975 were working within the same range of grain sizes. They differed chiefly in the proportions of cobbles and boulders that were encountered. The locations of these pits, by Towns, were as follows:

Beacon Falls.

1. West side of Naugatuck River, between Lopus Road and the railroad. Laverty and Hurley Co.

2. Southwestern quadrant of intersection of Bethany Road and Skokorat Road. Now used mainly for stockpiling and distribution. Hamden Sand and Gravel Co.

Bethany.

3. Group of pits north of Falls Road at the Bethany/Beacon Falls Town Line. Hamden Sand and Gravel Co.

Naugatuck.

4. Between Pond Hill Road and Mulberry Street.

5. North of New Haven Road and east of Candee Street, Mariano Sand and Stone Co.

6. West of Horton Hill Road, 0.3 mi. north of New Haven Road. Several bays. Leverty and Hurley Co.

Prospect.

7. South of Salem Road, near the northeastern corner of the quadrangle. Waterbury Sand and Gravel Co.

Seymour.

8. The group of pits immediately north of Bladens River and 0.3-0.5 mi. west of Miller Road.

The general distribution of sand and gravel in the quadrangle, together with the locations of operating pits and estimates of the volumes of material probably available, will be found in a report by Vitali (undated).

Landfill

The material most commonly used as artificial fill is till. It is comparatively abundant; also it contains a variety of grain sizes, including silt and clay, a characteristic that promotes compaction. Ordinarily, pits are created as fill is needed, at localities close to the areas to be filled, and are abandoned as filling is completed. The supply of till is still extensive, particularly in the parts of the area where the till cover is thick. Ice-contact stratified drift is also used as fill for many purposes.

Ground water

Various bodies of stratified drift within the area are potential sources of ground water for domestic use or for small industrial plants. However, because they consist of sand and gravel they are permeable, and the water table is generally low (in some places 25 ft or more below the surface), as well as rather closely adjusted to the level of tidewater or to that of the nearest surface stream. In consequence, the development of a reliable water supply from such material depends on thickness of the sediment in the zone below the water table. This is a matter for local investigation in each case.

Till is generally too thin and in some places too impermeable to be a source of water other than for shallow wells of low yield. Most users of water within the map area prefer to derive their supplies either from surface reservoirs or from wells drilled into bedrock.

Discussion of gound-water problems pertinent to the Naugatuck area will be found in reports by Ellis (1916) and Brown (1928).

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